

## U.S. Corporate R&D Investment, 1994 – 2000 Final Estimates

Despite a slowing economy, public corporations headquartered in the United States almost doubled the growth rate of their investment in research and development (R&D) in 2000 over 1999<sup>1</sup>. According to final estimates from the Office of Technology Policy's *U.S. Corporate R&D* data series, R&D investment rose sharply in current dollars from \$146.3 billion in 1999 to \$164.5 billion in 2000 or an increase of 12.4%. Even when the impact of inflation is accounted for, the rate of increase was still a substantial 9.9%.<sup>2</sup> The increase reversed a 5-year trend of slowing annual percentage increases in corporate R&D investment, and approached the recent inflation-adjusted high of a 10.3% annual increase set in 1995.

### **Data Background**

This report provides data on nine “**major sectors**” and at the sub-sector level, 46 “**detailed industries**,” based on the North American Industry Classification System (NAICS). Firms that invest a minimum of \$1,000 are included as R&D corporations. In addition to tracking total corporate R&D investment for specific sectors and industries, the report provides corresponding data on net sales, foreign sales, capital spending, employment, and numbers of corporations. While the report focuses primarily on firms that conduct R&D, it provides context by including the activity of all U.S.-headquartered corporations. In doing so, a more realistic picture is obtained for a number of industries that include a mix of R&D and non-R&D firms. Finally, the report tracks the activity of a specially identified collection of biotechnology corporations that permits examination of their performance against other industries for the first time.

The *U.S. Corporate R&D* data series is derived, in part, from *Standard and Poor's Compustat* database, which in turn is based on financial statements filed with the Securities and Exchange Commission (SEC). *Compustat* includes some 10,000 actively traded U.S. corporations (and 11,000 no longer active corporations) of which approximately one-third report R&D in a given year – amounting to a total of 4,895 firms during the period 1994-2000. Based on analysis of SEC filings and other sources, the Office of Technology Policy (OTP) substantially adjusts raw *Compustat* data to remove R&D double counts and write-offs of “acquired in-process R&D”<sup>3</sup> that are largely associated with firm acquisitions and mergers.

*U.S. Corporate R&D* data has a number of characteristics and limitations that should be considered in using the data and in comparing it to data available from other sources, such as the National Science Foundation (NSF).<sup>4</sup> For example, these data represent the total corporate R&D conducted in the United States and abroad by U.S.-headquartered corporations exclusively (unlike NSF data that represent total R&D expenditures conducted only in the U.S. by either U.S. or foreign-based firms). Therefore, these data exclude R&D performed in the

United States by foreign corporations that are headquartered abroad. Year-to-year percentage changes are reduced by foreign acquisition of U.S. corporations engaged in R&D here and abroad and are raised when U.S. corporations acquire foreign-owned businesses engaged in R&D. This report does not include estimates of the effects of such acquisition activity.

Finally, caution should be exercised in considering industry data over time - especially in highly turbulent sectors such as the *information and electronics manufacture and services* - since some annual changes in R&D and other indicators can be due in part or substantially to either (1) acquisitions, mergers, or spin-offs that reclassify certain R&D amounts from one industry to another or (2) the occasional reassignment of firms from one industry to another as their product lines change over time."<sup>5</sup>

## Data Presentation

The report provides graphics and numerical data in the following seven *Excel* files, subsections of which may be accessed by selecting "work sheet" tabs at the bottom of each of these files:

### Figures

- *Figure Series 1. U.S. R&D Corporations Total Aggregates & Major Sectors, 1994-2000*
  - Part 1. Total Aggregates – R&D & Non-R&D Corporations
  - Part 2. Major Sectors - R&D Corporations
  - Part 3. Major Sectors - R&D Corporations with Some Comparisons to Non-R&D Corporations
- *Figure Series 2. U.S. R&D Corporations - Detailed Industries, 1994-2000,*
- *Figure Series 3. U.S. R&D Corporations - Firm-Size Categories, 1998-2000*
  - Part 1. Firm-Size Categories
  - Part 2. Firm-Size Categories & Major Sectors
- *Figure Series 4. U.S. Biotechnology Corporations, 1994-2000*

### Tables

- *Table Series 1. U.S. R&D Corporations - Major Sectors & Detailed Industries, 1994-2000*
  - Highlights
  - Parts 1 –7 (each part provides separate coverage for R&D, net sales, capital spending, employment, firm counts, and acquired in-process R&D)
- *Table Series 2. U.S. R&D Corporations - Firm-Size Categories, 1998-2000*
  - Highlights

- Parts 1 –7 (each part provides separate coverage for R&D, net sales, capital spending, employment, firm counts, and biotechnology corporations)
- *Table Series 3. All U.S. Corporations - Major Sectors & Detailed Industries Categories, 1994-2000*
  - Parts 1 –7 (each part provides separate coverage for R&D, net sales, capital spending, employment, and firm counts)

Biotechnology corporate data is displayed in *Table Series 1* as a line item in most of the tables of that series. Biotech data is presented at the end of these tables in a separate box, underscoring the fact that this group of corporations is (1) not a NAICS-based industry category as are all major sector and detailed industries of this report, and (2) the biotech corporations are included in the standard NAICS-based industries of the report tables. *Table Series 2* presents biotechnology activity in a separate table section of its own (*Part 7*) and in several tables of the *Highlights* section.

#### Note

In the text below:

- All dollar amounts are expressed in current, or “nominal” dollars that are not adjusted for inflation.
- All dollar annual percent changes are expressed in 1996 dollars that are adjusted for inflation. 1996 dollars are calculated using the “implicit price deflator” published March 28, 2002 by the U.S. Department of Commerce, Bureau of Economic Analysis.
- The reported data covers 1994-2000 (except foreign sales which are unavailable for 1994 and firm-size data which includes only 1998-2000). Nevertheless, much of the discussion focuses on the latest trends, 1998-2000. Averaging the annual percentage changes for these three years minimizes annual fluctuations, the base year being 1997. The 1995-1997 period is similarly treated, the base year 1994 (except for foreign sales).

## Highlights

### **1. R&D corporations increased R&D investment significantly in year 2000**

In current dollars U.S. corporations invested \$164.5 billion of their own funds on R&D, an increase of 9.9% in 1996 dollars over the amount invested in 1999. [**Figure Series 1, Part 1**]

- Corporate R&D grew 7.3% annually in 1996 dollars over the three-year period 1998-2000, outpacing all other indicators except foreign sales as shown in the following table.

**Text Table 1 – R&D Corporations 1998-2000 Performance**

	<b>Year 2000</b> (dollar amounts are in billions of current dollars)	<b>1998-2000 average annual percent change</b> (dollar amounts are expressed in 1996 dollars)
Net sales	\$3,861.8	3.1% <sup>b</sup>
Foreign sales	\$1,183.4	11.1%
Capital spending	\$265.8	0.2%
Employment	14.5 million employees	0.5%

- Over the longer 1994-2000 period corporate R&D, net sales, and foreign sales grew 7.9%, 4.3%, and 8.4%, respectively, on an average annual basis in 1996 dollars.

## **2. Non-R&D corporations grew faster and had more sales than R&D corporations during the 1994-2000 period**

Dominated by the services sector, non-R&D corporations expanded faster in all indicators as shown in the following table. [**Figure Series 1, Part 1 & Part 3**]

**Text Table 2 – Non-R&D Corporations 1998-2000 Performance**

	<b>Year 2000</b> (dollar amounts are in billions of current dollars)	<b>1998-2000 average annual percent change</b> (dollar amounts are expressed in 1996 dollars)
Net sales	\$6,343.1	8.5%
Foreign sales	\$519.7	18.1%
Capital spending	\$512.1	9.4%
Employment	27.4 million employees	4.7%

- As a consequence, R&D corporations' shares of these indices fell from 43.5% in 1994 to 37.8% in 2000 for net sales, 77.7% to 69.5% for foreign sales, 40.5% to 34.4% for capital spending, and 38.6% to 34.7% for employment.
- These shifts say less about any relative "decline" of the R&D sector (except perhaps in basic industries and materials) than they do about how information industry innovations and strong sales spurred economic growth in general and services in particular.
- While the net sales of R&D-investing corporations in 2000 were relatively evenly distributed across the nine major sectors, 99% of non-R&D corporations sales originated from only three sectors: 69.4% from *various services* (mainly two industries: *wholesale and retail, transport and warehousing* and *finance, insurance, real estate and leasing*), 20.0% from *basic industries & materials*, and 9.9% from *information and electronics manufacture & services*. [**Figures 1.3.F and G**]

### **3. Growth varies widely by sector**

While the overall increase in corporate R&D investment suggests that many firms recognize the importance of technology competitiveness, the nine major sectors have significantly different R&D investment growth rates. [**Tables 1.1.A and 1.1.D, Figures 1.2.G and 2.C**]

- **Largest & fastest R&D sectors:** *Information and electronics manufacture and services (I&E)* is principally responsible for the overall increase in U.S. corporate R&D. The largest of the nine sectors as measured by absolute dollars of R&D investment; *I&E* invested \$77.8 billion current dollars in 2000. In second place, *medical substances and devices* invested \$32.5 billion. During 1998-2000 the R&D of these two sectors grew at average annual rates of 11.7% and 8.1% in 1996 dollars, respectively with net sales also expanding rapidly. [**Table 1.2.D**] Only, **various services**, which invested \$2.9 billion current dollars in R&D in 2000, grew faster. Its investment expanded at 29.2% annually in 1996 dollars with the *electronic shopping & mail order* industry leading at 166.3% annual growth in R&D investment.<sup>7</sup>

Of the larger industries within the major sectors, six *I&E* industries (investing between \$4.4 and \$15.6 billion current dollars each in 2000) experienced the most impressive R&D growth rates during 1998-2000. On an annual basis as measured in 1996 dollars:

- *software publishers* R&D investment expanded 20.9%,
- *semiconductor & related device manufacture*, 20.3%,
- *radio, TV & wireless communications equipment manufacture*, 15.9%,
- *instrument manufacture*, 13.4%,
- *electronic computer manufacture*, 11.6%,
- *telephone apparatus manufacture*, 11.3%.

*Pharmaceutical and medicine manufacture* R&D investment expanded at 8.8% annually in 1996 dollars. The sector reached a \$24.6 billion current dollar investment level in 2000.

- **Lagging R&D sectors:** Three major sectors experienced negative or near zero R&D growth during 1998-2000 with sales also down from previous years.
  - *Basic industries & materials* R&D investment was \$8.6 billion current dollars in 2000. In 1996 dollars this translates as a decline of 3.6% annually over 1998-2000 with eight of 11 industries experiencing falling R&D investment. With only 0.5% annual growth during the previous 1995-1997 period, the sector's 2000 R&D investment was below its 1994 level

by \$0.8 billion in 1996 dollars. Sales growth was also sluggish in 1998-2000 at 0.4%.<sup>8</sup>

- *Aerospace* R&D investment in 2000 was \$5.0 billion current dollars. This represents an annual decline of 0.6% in 1996 dollars over 1998-2000. R&D growth was only slightly stronger at 1.6% annually during the previous three years. At 1.3% growth, net sales for this highly cyclical sector were down considerably in 1998-2000 from the previous three years, despite significant increases in foreign sales.
- *Surface transport equipment manufacture* During 1998-2000, R&D investment slumped to 0.1% annual growth in 1996 dollars. \$19.8 billion current dollars were invested in 2000. Net sales also slowed to 1.6% annually. However, a portion of the drop from higher growth in previous years is attributable to corporate acquisition activity, such as the purchase of the Chrysler Corporation by Daimler-Benz, which removed Chrysler from the list of U.S. corporations between 1997 and 1998.
- **Moderate R&D growth sectors:** The *chemical manufacturing* and *machinery manufacturing* sectors respectively increased R&D investment by 3.9% and 3.3% annually in 1996 dollars during 1998-2000. With a \$8.9 billion current dollar investment in 2000, *chemical manufacture* steadily increased the pace of its R&D growth rate over the three-year period, reversing contractions of previous years. *Machinery manufacturing* R&D investment reached \$6.9 billion in 2000, following rather uneven growth during the three-year period.
- **Varying growth rates shifted the distribution of U.S. corporate R&D:** In 1994, *I&E* and *medical substances and devices* respectively invested 37.8% and 17.9% of all U.S. corporate R&D. In 2000, these shares increased to 47.3% and 19.8%, respectively. In contrast the slow growing *basic industries & materials* sector share slipped from 9.1% to 5.2%, *surface transport equipment manufacture* declined from 16.3% to 12.0%, and *chemical manufacture* dropped from 8.0% to 5.4% of total U.S. corporate R&D investment by public R&D corporations. **[Figure 1.3.H]**

#### **4. Medical sector had highest R&D intensity**

Of the major sectors, *medical substances and devices* had by far the highest R&D intensity as measured by both the percentage ratio of R&D to sales and R&D investment per employee.<sup>9</sup>

- During 1998-2000 the R&D corporations of the medical sector experienced a combined annual average R&D/sales ratio of 12.3% and \$29.32 per employee – almost double the intensities of the *I&E* sector at 7.3% and \$16.47, respectively.

- The least intensive sectors were *various services* at 0.8% and \$1.18 and *basic industries & materials* at 0.9% and \$2.75.
- For R&D corporations only, overall intensities were 4.2% R&D/sales and \$9.80 R&D investment per employee. For combined R&D and non-R&D corporations, overall intensities are diluted substantially at 1.6% and \$3.42, respectively [**Figure 1.3.J**].

Of industries within major sectors *non-diagnostic biological product manufacture* had the greatest intensities: 38.6% R&D/sales and \$95.21 R&D per employee. The next six most intensive industries had R&D/sales ratios ranging from 12.3% to 28.4% and investments of R&D/employee amounts ranging from \$30.76 to \$42.69. [**Figure 2.J**]

- *In-vitro diagnostic substance manufacture*
- *Semiconductor industry machine manufacture*
- *Software publishers*
- *Pharmaceutical and medicine manufacture*
- *Telephone apparatus manufacture*
- *Semiconductor & related device manufacture*

## **5. R&D and sales growth tend to correlate across industries**

**Figure 2.H** shows a generally consistent correlation between industry R&D and net sales growth rates in 1998-2000. That is, growth in R&D investment trends higher as sales growth increases. A close relationship is not unexpected since the amount of company funds available for R&D investment often depends on the company's sales or "cash flow" performance in the current and immediately preceding years. On the other hand, given that investment in R&D is frequently undertaken with the intention of achieving higher sales, for industries in which technological competitiveness is critical, R&D investment may spur sales growth.

## **6. Information-related industries led in overall growth performance [Figure 2.B]**

For all R&D corporations, six of the top ten growth industries were from the I&E sector (collectively representing 28.6% of U.S. corporate R&D and net sales of \$464 billion). **Figure 2.B** ranks larger individual industries (having \$350 million or more R&D and 100,000 or more employees in 2000) by their average overall growth performance in five indices during 1998-2000: R&D, net sales, foreign sales, capital spending, and employment. Perhaps not surprisingly, eight of the ten top overall performance industries were also among the top ten R&D growth industries. [**Figure 2.C**] In rank order the industries are:

- *Electronic computer manufacture*
- *Semiconductor and related device manufacture*
- *Software publishers*
- *Administrative support, waste management and remediation services*
- *Other electronic components manufacture*
- *Telephone apparatus manufacture*
- *Professional, scientific, and technical services except computer*
- *Radio, TV broadcasting and wireless communication equipment manufacture*
- *Wholesale and retail, transport and warehousing*
- *Unclassifiable & conglomerates*

With dollar amounts expressed in inflation-adjusted 1996 dollars, the average annual growth rate (unweighted) for the top ten performing industries during 1998-2000 in each of the five indices was:

- R&D investment, 17.4%
- Net sales, 12.3%
- Foreign sales, 29.8%
- Capital spending 13.7%
- Employment, 9.7%

If smaller industries are included (as they are in **Table 1.0.C**), the following industries would be among the top ten overall performers:

- *Electronic shopping and mail-order*
- *On-line information services*
- *In-vitro diagnostic substance manufacture*
- *Semiconductor industrial machinery manufacture*
- *Non-diagnostic biological product manufacture*

## **7. Basic industries and materials experienced poorest overall growth performance**

As **Figure 2.B** shows, for R&D corporations, eight of the ten industries with the worst overall growth performance during 1998-2000 are from the *basic industries and materials* sector (even though **Figure 2.B** includes the *computer peripheral equip. and terminal manufacture* among the bottom ten performers it is excluded here since its performance is largely due to statistical distortions attributable to acquisitions by firms in other industries). Notably, of the poorest performance industries, seven were also among the ten industries with greatest decreases in R&D investment. [**Figure 2.C**]

With dollar amounts expressed in inflation-adjusted 1996 dollars, the average annual growth rate (unweighted) for the worst ten performing industries during 1998-2000 in each of the five indices was:

- R&D investment, -3.0%
- Net sales, -1.3%
- Foreign sales, 3.7%
- Capital spending -7.4%
- Employment, -4.5%

## **8. Foreign sales climbed dramatically in 1998-2000**

The growth rate of foreign sales by R&D-investing corporations jumped from a 4.6% average annual rate in 1996-1997 (**Note** - 1994 foreign sales are unavailable from *Compustat*) to 11.1% in 1998-2000 as expressed in 1996 dollars. If not for exceptional declines in petroleum industry foreign sales, the increase would have been higher. At \$1.2 trillion in 2000, the ratio of foreign sales to total net sales were 30.6%, up from 25.7% in 1998.

All major sectors except *basic industries and materials* increased their foreign sales during 1998-2000. [**Figures 1.2.C, G & L and Table 1.3.F**] The sectors with the most significant percentage increases since 1997, and which also had the highest ratio of foreign sales as a percent of net sales (intensity ratio) are listed in the following table:

**Text Table 3 – Major sectors with significant increases in foreign sales**

	<b>Year 2000 increase over 1997</b> (billions of current dollars)	<b>1998-2000 average annual percent change</b> (1996 dollars)	<b>Year 2000 foreign sales as a percent of total net sales</b>
<i>Aerospace</i>	\$49.6	8.5%	43.8%
<i>I&amp;E</i>	\$180.5	18.1%	38.2%
<i>Machinery manufacture</i>	\$30.8	9.4%	37.6%
<i>Chemical manufacture</i>	\$33.9	4.7%	41.6%

Text Tables 4 & 5 below list individual industries with large amounts of foreign sales that had significant increases or decreases in foreign sales intensity between 1995 and 2000. The industries are ranked by magnitude of foreign sales/net sales intensity change.

**Text Table 4 - Industries with significant increases in foreign sales intensity, ranked by amount of intensity change**

Industry	Foreign sales as a percent of total net sales		Foreign sales, 2000, billions of dollars
	1995	2000	
Semiconductor industrial machinery manufacture	6.3%	55.2%	\$10.3
Aerospace	12.5%	43.8%	\$64.9
Paint, coatings, adhesives, cleaning, surface agent manufac.	10.9%	36.7%	\$31.8
Agri., construction, mining machinery manufacture	14.9%	39.9%	\$21.4
Electronic computer manufacture	19.2%	44.1%	\$45.2
Instrument manufacture	11.9%	35.1%	\$20.6
Other electronic components manufacture	22.2%	42.8%	\$21.1
Semiconductor and related device manufacture	32.4%	52.5%	\$56.1
Telephone apparatus manufacture	12.6%	30.8%	\$15.1
Electrical equip., appliance and component manufacture	15.7%	30.4%	\$23.6
Software publishers	22.2%	32.7%	\$30.2

**Text Table 5 - Industries with decreases in foreign sales intensity, ranked by amount of intensity change**

Industry	Foreign sales as a percent of total net sales		Foreign sales, 2000, billions of dollars
	1995	2000	
Petroleum and coal products manufacture	34.0%	20.3%	\$81.7
Fabricated metal product manufacture	44.0%	33.8%	\$20.2
Admin., support, waste management and remediation services	48.6%	45.7%	\$9.4
Pharmaceutical and medicine manufacture	30.4%	29.2%	\$59.4
Computer systems design and related services	54.0%	53.2%	\$63.1

**Figure 2.K** ranks industries by their average 1998-2000 foreign sales intensities with comparisons to their 1995-1997 averages.

## **9. R&D major sectors consolidated in 1998-2000**

After expanding from 2,856 firms in 1994 to a peak of 3,591 in 1998, the total number of R&D corporations rapidly contracted over the next two years to 3,090 in 2000.

- The preponderance of this contraction occurred in the largest major sector, *I&E*, which contracted 15.0% from a peak of 1,801 firms in 1998 to 1,530 firms in 2000. [**Figure 1.2.H**]
- Similar contractions occurred in other sectors: *medical substances & devices* dropped 11.5% from a high of 644 firms in 1998 to 570 in 2000; and *various services*, which includes *electronic shopping*, dropped 12.4% from its 1999 peak of 291 firms to 255 firms in 2000.

- *Basic industries and materials* began its contraction earlier, eroding 24.7% from a peak of 427 firms in 1995 to 322 in 2000. *Machinery manufacture* also began to decline early, contracting 25.3% from a peak of 277 firms in 1996 to 207 in 2000.

## **10. R&D industry “turbulence” ebbed as firm entries declined**

For R&D corporations, commencements or terminations of R&D may be used as a proxy for measuring industry “turbulence” – defined here as the rate at which firms *enter* (R&D commencement) and *exit* (R&D termination) a particular industry.<sup>10</sup> For the 33 largest industries **Figure 2.L** reports the percentage of firms that either commenced or terminated the reporting of R&D over the two-year periods 1995-1996 and 1999-2000 (1995 is the first year for which firm *entries* can be calculated). A third component of turbulence, changes in market share, is not reflected.

Despite a separation of only three years, the two periods contrast markedly:

- During the more turbulent 1995-1996 period, an annual average of 15.6% of all firms were *entries*, while only 6.6% annually were *exits*. At that time 30 of 33 industries experienced more *entries* than *exits*.
- The opposite situation occurred in 1999-2000 when on an annual average basis only 4.3% of all firms were *entries* and 11.5% were *exits*. In this later period only two of 33 industries experienced more *entries* than *exits*.

On an industry basis, the transformation from the earlier to later period could be extreme. For example:

- Within the *I&E* sector, in 1995-1996 71.2% annually of all *on-line information services* firms were *entries* and only 6.3% were *exits*. In 1999-2000 this reversed to 10.3% *entries* and 14.1% *exits*. *Software publishers* switched from 30.5% *entries* and 6.2% *exits* to 4.2% *entries* and 10.0% *exits*. *Computer systems design and related services* switched from 28.4% *entries* and 7.9% *exits* to 4.7% *entries* and 11.4% *exits*.
- Within the *medical* sector, *non-diagnostic biological product manufactures* switched from 24.9% *entries* and 4.6% *exits* to 1.2% *entries* and 9.0% *exits*.

The overall increase in the number of firm exits in 1999-2000 predominantly reflects the transition of technology industries from a phase in which many entrepreneurs pursued innovation by establishing new firms, to a consolidation phase in which firms sought to bolster their technological position and opportunities by acquiring other firms. In 2000, for example, Cisco Systems acquired approximately 20 firms. Additionally, as the economy slowed in 2000, *exits* accelerated as a consequence of business failure.

## **11. Middle-sized R&D firms grew fastest**

The activity of 2,775 U.S. R&D corporations by firm-size category is covered by **Figure Series 3** and **Table Series 2** for the years 1998-2000. The firms are grouped into 10 categories based on number of employees. In considering this data, it is important to note that these categories include only firms that reported R&D in all three years and that a given firm's size categorization is based on its average number of employees over the three-year period. In other words, growth rates do not reflect the entry of any new firms, the exit of expired or acquired firms, or the movement of firms from one size category to another (due to size averaging). By excluding entries and exits, the growth rates of this particular population may be somewhat different from the larger population of all R&D corporations featured in this report.

- **R&D investment is concentrated in the largest firms.** In 2000 the 273 firms with 10,000 or more employees invested 70.7% of all the R&D conducted by the 2,775 firms examined – a decline from a 74.1% share in 1998. The remaining 2,506 corporations with less than 10,000 employees conducted the balance of 29.3% in 2000. [**Figure 3.1.G**]
- Net sales were even more concentrated in the largest firms. The top 273 generated 83.8% of total U.S. corporate R&D sales in 2000 [**Figure 3.1.H**], which underscores the fact that R&D intensity (the ratio of R&D to sales or R&D dollars per employee) is generally inversely related to firm size. In 2000, firms with more than 50,000 employees had a combined R&D/sales ratio of 3.4%. As **Figure 3.1.I** shows, R&D intensity climbs steadily as firm size decreases reaching 79.9% for firms with less than 50 employees.<sup>11</sup>
- **Firms with 250-499 employees out-paced all other categories in all tracked indices.**
  - In 1996 inflation-adjusted terms, during 1999-2000 the 425 corporations in this category saw R&D grow 35.0% annually, net sales grow 33.2%, foreign sales grow 67.2%, and capital spending grow 68.6%. Employment expanded by 15.8% annually. [**Figure 3.1.F**]
  - The other four small to middle-sized firm-size categories (between 50-2,499 employees) also grew impressively with R&D growth rates above 16.4% annually in 1996 dollars and sales increases more than 11.6% annually.
  - The smallest firm category, 49 or fewer employees, had the worst overall performance, including the only decline in R&D (-0.4% annually in 1996 dollars) and the lowest growth for net sales, foreign sales and capital spending.

- The largest category (50,000 or more employees) turned in the second lowest performance.
- **Significance of fast growing mid-sized firms may be greater than the numbers suggest.** In absolute terms larger R&D firms generated significantly greater amounts of R&D, products, sales, and new jobs by virtue of their sheer size. Nevertheless, for several reasons, the overall economic contribution of smaller, rapidly growing firms may be disproportionately greater than is apparent quantitatively.
  - First, the R&D investments of these firms may generate more innovation than equal dollar investments by large firms. For example, entrepreneurs establish technology firms specifically to create and commercialize new technologies that large corporations may not so effectively undertake. In contrast, while certainly necessary, much of the R&D conducted by larger companies is devoted to incremental improvements of existing product lines and processes rather than the introduction of significantly new or groundbreaking technologies.<sup>12</sup>
  - Second, in highly competitive industries with high rates of entry, fast growing smaller and mid-sized firms often set the pace for innovation, spurring large firms to bolster their own research and technological competitiveness. This was the case in the 1980s when Microsoft and small computer manufactures drove IBM to transform itself into the information technology powerhouse it remains today. In this sense, aggressive new ventures may “pull” the overall R&D enterprise of competitive industries.
  - Finally, some analysts believe that R&D conducted by smaller firms is significantly under-reported. This may be due, in part, to small firms’ emphasis on applied research and development rather than fundamental research, and because the R&D activity is often informally organized and not as systematically accounted for as it is in large firms.<sup>13</sup> Additionally, a significant number of smaller technology firms have compensated R&D workers with stock options. The extent to which such remuneration is reliably reported as R&D expense is unclear.

## **12. Fast growing information & electronics firms drove rapid growth of middle firm-size categories**

- For each category **Figure 3.2.A** displays the R&D percentage shares of the nine major sectors, which vary considerably from one category another.
  - **I&E firms perform the majority of R&D in the seven categories ranging from 100 to 49,999 employees:** Of the four fastest growing

overall categories with 100 to 2,499 employees [**Figure 3.1.F**], *I&E* contributes 66.1% of the R&D. Eighty percent of the R&D performed in the 500-999 employee firm-size category is *I&E*.

- **The firm-size category distribution of *medical substances and devices* R&D is somewhat the inverse of the *I&E* pattern.** Medical firms perform the bulk of the R&D conducted by the two smallest firm-size categories (70.2% for firms with less than 50 employees), but only 7.8% for the mid-sized category of 500-999 employees.

With respect to the medical sector firms that dominate the two smallest firm-size categories it is interesting how markedly their overall performances contrast during 1999-2000. The 108 medical firms in the 50-99 employment category performed well, only slightly below most other medical sector categories. During the three-year period these firms had average annual growth rates in 1996 dollars of 15.8% for R&D, 20.2% for net sales, 19.3% for foreign sales, and 5.2% for capital spending. Employment grew 8.8% annually. But the 146 medical firms in the smallest firm-size category with 49 or fewer employees performed less well: respectively -3.6%, 6.5%, 5.9%, and -5.0%. Employment was 1.3%.

- **Mid-sized *I&E* firms experienced exceptional overall growth. *Figure 3.2.D-1&2*** ranks from top to bottom the firm-size categories of the nine major sectors by overall 1999-2000 growth performance in five indices. Four *I&E* categories with between 100 and 2,499 employees are among the top five sector-specific firm-size categories in this chart. Average annual 1999-2000 growth rates in 1996 dollars for these four *I&E* firms-size categories range as follows:

- R&D investment, 34.6% – 59.3%
- Net sales, 22.0% – 40.0%
- Foreign sales, 42.8% – 87.8%
- Capital spending, 55.9% – 92.0%
- Employment, 12.4% – 21.0%

Mid-sized categories of the *various services* sector and the *medical substances and devices* sector also ranked among the top performing sector-specific firm-size categories.

### **13. Biotechnology corporations**

Biotechnology increasingly influences U.S. economic productivity and national security in numerous industrial processes, products, healthcare, and agriculture. Presently, however the U.S. Government does not collect comprehensive statistics on the U.S. biotechnology industry. This is largely because biotechnology is a rapidly developing sector and because the North American

Industry Classification System (NAICS) does not provide a separate classification for biotechnology.

- **Identifying biotechnology firms:** In order to improve understanding of this important technology sector, this report analyzes the activity of specially identified biotechnology corporations otherwise classified in the *U.S. Corporate R&D* data series. Biotech corporations were identified using primarily the *BioAbility* database (formerly the Institute for Biotechnology Information),” along with the *Corptech* database, produced by *OneSource*, the membership of *BIO (the Biotechnology Industry Organization)* and several biotechnology-related databases available on the Internet.<sup>14</sup>

Identified corporations include public corporations that:

- engage in biotechnology R&D,
- create biotechnology products or research tools, and/or
- use biotechnology processes in their manufacturing.<sup>15</sup>

An attempt is made to include corporations that are primarily engaged in biotechnology activity and to exclude companies that are generally characterized otherwise. Excluded, for example, are large multi-division pharmaceutical firms and conglomerates. While such excluded firms may conduct important biotechnology activity it is not possible to separate this activity from other significant research and business activity. Therefore, the biotechnology corporations here do not represent all U.S. corporate biotech activity.

Biotechnology graphics are found in *Figure Series 4*. Tabular biotechnology corporate data is displayed in *Table Series 1* as a line item in most of the tables of that series. *Table Series 2* presents biotech firm-size category activity in *Part 7*.

- **Biotech firms are 10 percent of R&D firms:** Of the 4,895 firms in the *U.S. R&D Corporate* data series, 392 were identified as biotechnology corporations during the 1994-2000 period. Not all of these firms were extant at the same time: 220 performed R&D in 1994, 343 in 1998, and 310 in 2000 after a contraction similar to that of R&D firms in general.<sup>16</sup> [**Figure 4.E.**] In 2000 biotechnology firms represented 10.0% of active R&D corporations.
- **Nearly 4 of 5 identified biotech firms employed less than 250 employees:** Of 295 U.S. biotech R&D corporations that reported R&D over the entire three-year period (1998-2000), 79.0% had less than 250 employees. This compares to 46.7% for the larger population of U.S. R&D corporations.<sup>17</sup> Only 5 firms had more than 2,500 employees.<sup>18</sup> [**Figure 4.H**]
- **Biotech “turbulence” abates in 2000 as firm entries drop:** During the two-year period 1999-2000, R&D corporations generally saw greater “turbulence”

than did biotech firms. Overall, R&D corporations averaged 4.3% annual *entries* (as measured by R&D. commencements) and 11.5% *exits* (R&D terminations); whereas biotech firms averaged only 2.2% *entries* and 7.1% *exits*. Previously, biotech experienced two recent years with high levels of firm *entries* -- 1995 (61) and 1998 (66). 2000 saw only 2 *entries*. *Exits*, however, crept up from a low of 5 in 1997 to a high of 26 in 2000. [**Figure 4.H**]

- **A fifth of biotech firms are classified in industries other than medical:** Under NAICS, biotech corporations active in 2000 are classified in the U.S. R&D corporate data series in the following sectors:
  - *medical substances and devices*, 80.9%;
  - *various services*, 9.2% (the majority classified as non-computer related professional, scientific, and technical services; the remainder chiefly as health care services);
  - *information & electronics manufacture and services*, 5.1% (the majority classified as instrument manufacturers; most of the remainder as software publishers);
  - *basic industries and materials*, 2.3% (all but one classified as agriculture-related); and
  - *chemical manufacture*, 2.0%
- **Biotech R&D grew at nearly twice the total corporate rate in 1998-2000, and outpaced all but one major sector:** Overall, biotech corporate R&D investment grew 13.2% annually in 1996 dollars over the three-year period. It totaled \$8.8 billion current dollars in 2000. [**Figures 4.A and 4.B**]
  - In comparison, total corporate R&D grew 7.3% annually in 1996 dollars, while two fast growing major sectors, *I&E* and *medical substances and devices*, respectively grew 11.7% and 8.1% annually. Only *various services* grew faster at 29.2% annually.
  - Like other sectors, biotech R&D growth decelerated from the previous three-year period, coming down from an 18.3% annual rate in 1995-1997.
  - In 2000 biotech R&D represented a 5.4% share of total corporate R&D, up from 3.5% in 1994 when biotech R&D totaled \$3.3 billion current dollars.
  - Notably, 16 biotech firms reported a total of \$1.5 billion in write-offs of acquired in-process R&D (IPR&D) in 2000, while 8 biotech firms reported a total of only \$115 million in IPR&D during 1999. [**Figures 4.A**] As noted in the “Data Background” section of this report and accompanying endnote, *Compustat*, the primary data source for this report, combines corporate internal R&D expenditure with write-off of acquired IPR&D and reports these as a single R&D expense. This practice mixes together real-time R&D expense with acquired IPR&D write-off, which is an estimate of future value (and the expense of which is likely already accounted for in

the R&D of firm from which technology is acquired). In order to avoid substantially overstating actual R&D performance, this report excludes IPR&D. Had this IPR&D not been excluded in 1999 and 2000, the biotech R&D increase in the latter year would be 32.8% in 1996 dollars rather than 15.4%. Not all *Compustat*-based R&D reports exclude IPR&D or make other data adjustments such as removing double-counts that may occur when firms with different fiscal years merge.

- **Mid-sized biotech R&D grew fastest:** Biotech firm-size categories with 50 to 2,499 employees increased their R&D investment between 20.3% and 29.5% annually in 1996 dollars over the two-year period 1999-2000. [**Figure 4.H**] In comparison, the average growth for all biotech corporations was 19.9% annually over the two-year period.<sup>19</sup>

Other biotech firm-size categories experienced the following R&D investment average annual percentage changes in 1996 dollars during the 1999-2000 period:

- 5,000-9,999 employees, 18.0%
  - 2,500- 4,999 employees, 11.5%
  - 49 or fewer employees, -4.0
- **Biotech firms with 100 to 249 employees conducted more R&D than other firm-size categories in 2000:**
    - Eighty-nine biotech firms with 100-250 employees invested a total of \$2.0 billion R&D current dollars for an average firm investment of 22.8 million.
    - Averaging 38.0 million per firm, 36 biotech firms with 250-499 employees invested a total of \$1.4 billion current dollars in R&D. The thirteen firms with 1,000-2,499 employees also invested a combined amount of \$1.4 billion for an average of \$110.7 per firm.
    - At \$410 million current dollars, the eight firms with 500-999 employees made the smallest firm-size category investment in R&D, averaging \$51.2 million per firm. The 81 firms with 49 or fewer employees made the second smallest investment at \$457 million, averaging \$5.6 million per firm.
  - **Overall biotech R&D intensity in 1998-2000 was 8 times greater than the corporate average:** Biotech corporations are among the most R&D intensive of all technology firms with a three-year average ratio of R&D to sales of 34.3% and an average expenditure of \$73.56 R&D per employee. This compares to 4.2% and \$9.80 respectively for all corporations and \$12.3 and \$29.93 for *medical substances and devices*, which has the highest intensity of

the major sectors. Biotech intensities were somewhat higher during the 1998-2000 time-period than in 1995-1997 time-period. [**Figure 4.C**]

**Smaller biotech firms had extremely high R&D intensities with R&D exceeding sales:** Like most firms, biotech R&D intensity levels rise as firm size decreases. However, as a group, biotech intensities are significantly greater. [**Figure 4.M**] The smallest firm-size categories experienced exceptionally high R&D intensities, reflecting the fact that many of these firms had not yet achieved sales:

**Text Table 6 – High R&D intensity firm-size categories**

	R&D intensity, 1998-2000 average	
	R&D/sales	R&D per employee
Firms with 49 or fewer employees	306%	\$213.70
Firms with 50-99 employees	228.6%	\$169.43
Firms with 100 - 249 employees	110.3%	\$111.87

- **Growth in biotech sales, capital investment, and capital expenditure slowed in 1999 and 2000:** While foreign sales growth remained relatively robust, formerly vibrant net sales growth flattened in the two latest years, and after strong increases through 1998, both capital spending and employment declined in 1999 with modest recoveries in 2000. [**Figure 4.A**] The slowdown may stem from several factors including failure to meet earlier high expectations regarding the number of biotech products that would become available, the high cost of regulations and clinical trials, and consumer resistance to certain biotechnology in the U.S. and abroad, particularly regarding agriculture-related products.<sup>20</sup>

Average annual growth performance in these indices over two three-year periods, 1995-1997<sup>21</sup> and 1998-2000 are highlighted in the following table and can be viewed in **Figure 4.B**<sup>22</sup>

**Text Table 7 – Biotech growth in four areas**

	Average annual percent change (dollar amounts in 1996 dollars)	
	1995-1997	1998-2000
Net sales	20.2%	7.1%
Foreign sales	28.9%	13.9%
Capital spending	21.1%	4.3%
Employment	16.6%	5.5%

- **Biotech firms with 100 to 249 employees led in overall growth performance:** In 1996 dollars, during 1998-2000 such firms saw annual increases for R&D of 27.0%, net sales of 24.8%, foreign sales of 33.0%, and capital spending of 42.5%. Employment increased 12.9%. **Figure 4.L** ranks firm-size categories by their average overall growth performance in all five

indices during 1998-2000. Firms with 500-999 employees performed second best overall.

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<sup>1</sup> Year 2000 data includes R&D and other activity data reported by corporations with fiscal years ending between June 1, 2000 and May 31, 2001. The majority of corporations reported in December of 2000.

<sup>2</sup> Unless otherwise indicated all annual percent changes are expressed in 1996 dollars that are adjusted for inflation. 1996 dollars are calculated using the "implicit price deflator" published March 28, 2002 by the U.S. Department of Commerce, Bureau of Economic Analysis.

<sup>3</sup> In reviewing this data and comparing it to R&D data available from other sources it is important to take into account that the *U.S. Corporate R&D* data series excludes billions of dollars of acquired in-process R&D (IPR&D) write-offs that are reported by *Compustat* for numerous corporations. According to generally accepted accounting practices, corporations can write-off IPR&D when they acquire technology, which oftentimes occurs when another company is acquired. However, *Compustat* "standardization" practice (current at the time the data of this report was assembled) usually combines corporate internal R&D expenditure with write-off of acquired IPR&D and reports these as a single R&D expense. This practice mixes together real-time R&D expense with acquired IPR&D write-off, which is an estimate of future value (and the expense of which is likely already accounted for in the R&D of firm from which technology is acquired). Reported IPR&D valuation often significantly exceeds the amount an acquired firm previously spent on R&D. As a consequence, users of *Compustat* -derived data may draw inaccurate conclusions regarding the R&D activity of certain companies or sectors, especially if IPR&D are considerable, some in excess of \$1 billion. To avoid this problem these IPR&D amounts are excluded to ensure aggregate corporate R&D investment amounts are not overstated. While *Compustat* has provided certain supplemental data on IPR&D write-offs that are helpful, the coverage is incomplete and has been necessarily supplemented by the individual review of SEC submissions of those companies with unusually high R&D increases.

<sup>4</sup> The following is a list of some *U.S. Corporate R&D* data series structural characteristics and differences between it and NSF's SRS data series, which is based on data collected by the Bureau of Census:

*U.S. Corporate R&D* includes only publicly held firms, whereas the SRS data series includes both publicly and privately held firms.

*U.S. R&D*-investing firms that switch from private to public ownership enter the *U.S. Corporate R&D* data series. Conversely publicly held firms that revert to private ownership exit the data series. Switches in ownership status do not influence the SRS data series.

In contrast to the SRS data series, *U.S. Corporate R&D* generally attributes R&D investment to the firm that is the source of the R&D funds, not the performer of the R&D (i.e., not contractors). This fact, for example, explains why the SRS data series attributes a much larger amount of R&D performance to R&D service firms than does *U.S. Corporate R&D*.

*U.S. Corporate R&D* includes U.S. firm R&D conducted abroad, while the SRS data series excludes it.

*U.S. Corporate R&D* excludes R&D conducted in the United States by firms headquartered outside the United States, whereas the SRS data series includes such R&D.

The R&D investments of foreign firms that are acquired by U.S.-headquartered firms may be added to the *U.S. Corporate R&D* total. Conversely, U.S.-headquartered firms that are acquired by foreign-headquartered firms are no longer included in the data series after the date of acquisition. The SRS data series is unaffected by change in national affiliation of a given firm or subsidiary conducting R&D in the United States.

*U.S. Corporate R&D* does not include the R&D expenditures of banks, utilities, and property and casualty companies, while the SRS data series includes the R&D of such companies.

<sup>5</sup> In recent years some major corporate activity moved corporate assets that were previously classified in one industry to another industry, thereby causing significant increases or drops in effected industry sector R&D levels (and other indicator levels). Some major shifts include the following (with percent changes calculated in 1996 dollars):

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1. 1995 - *Telephone apparatus manufacture* industry R&D increased 387% while the *broadcasting and telecommunications* industry R&D dropped 69% in the same year AT&T spins off Lucent Technologies.
  2. 1998 - The foreign firm Daimler-Benz acquired Chrysler Corporation thereby reducing R&D investment for the *surface transport equipment manufacture* industry to a level below that of 1997.
  3. 1999 - *Agriculture, forestry, fishing and hunting* industry R&D drops 69% in the same year that Dupont acquires Pioneer Hi-Breed International and Monsanto acquires Dekalb Genetics Corp.
  4. 2000 - *All other chemical product manufacture* industry R&D increases 38% in the same year that "new" Monsanto emerges from Pharmacia-Monsanto merger focusing on agricultural chemical manufacture.
  5. 1999 - *Computer peripheral equipment and terminal manufacture* industry R&D drops 10% in the same year that Hewlett-Packard spins off Agilent Technologies and the latter is classified in the *instrument manufacture* industry. However the addition of these assets in that industry is countervailed by the shift of Allied-Signal's assets out of the *instrument manufacture* industry to the *aerospace* industry when it merges with Honeywell to become Honeywell International.
  6. 2000 - *Computer peripheral equip. and terminal manufacture* industry R&D increases 22% in the same year that Cisco Systems significantly increases its R&D investment mostly due to multiple corporate acquisitions.
  7. 2000 - *Radio, TV broadcasting and wireless communication equipment manufacture* industry R&D increases 33% in the same year Motorola significantly increases its own R&D and Avaya Inc. assets are added to the industry after being spun off from Lucent Technologies in the *telephone apparatus manufacture* industry, which as a consequence experienced zero R&D growth in 2000.
  8. 2000 - *Engine, turbine, and power transmission equipment manufacture* industry R&D drops 33% in the same year that the foreign firm Daimler-Chrysler AG acquires the Detroit Diesel Corp.

<sup>6</sup> Notably, overall net sales by U.S. R&D-investing corporations were depressed by the singular event of the 1998 slide in oil prices that caused sales for all R&D corporations to decline 1.8% in that year (1996 dollars). Excluding the petroleum and chemical-related sectors that were most effected by this event, R&D corporations net sales grew in 1996 dollars 2.5% in 1998 and for 1998-2000 4.8% on an average annual basis.

<sup>7</sup> More than one half of all the *electronic shopping and mail order* industry R&D expenses in year 2000 are attributable to one company. The company refers to these R&D expenses as "technology and content" expenses. In its 10K-405 submission of March 23, 2001 to the SEC the company describes these expenses as follows: "Technology and content expenses consist principally of payroll and related expenses for development, editorial, systems and telecommunications operations personnel and consultants; systems and telecommunications infrastructure; and costs of acquired content, including freelance reviews. Technology and content expense was \$269 million, \$160 million and \$46 million for 2000, 1999 and 1998, representing 10%, 10%, and 8% of net sales for the corresponding periods. The increase in absolute dollars spent during 2000 and 1999 were primarily reflective of our continual enhancements to the features, content and functionality of our Web sites and transaction-processing systems, as well as increased investment in systems and telecommunications infrastructure."

<sup>8</sup> While non-R&D corporations of this sector experienced better sales performance, most of these firms were in the *other basic industries activity* industry, which does not include many R&D firms [Tables 1.2.D and 3.2.D].

<sup>9</sup> Some caution should be taken in considering R&D intensity ratios. First, while R&D-to-sales ratios and R&D-per-employee reflect differences among industries in their relative reliance on R&D, depending on the situation, differences in intensities may arise from any number or combination of factors such as intended competitive strategies, cost factors associated with differing scientific and technological disciplines, or circumstances beyond the control of management. For example, in the case of the pharmaceutical industry, R&D is performed not only for the sake of discovering new products, but also for the sake of product testing to meet regulatory requirements once a new product has been designed. A change in

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such regulatory requirements might, therefore, change the amount of R&D conducted without changing the number or value of new products being developed. Furthermore, regarding R&D-to-sales ratios, for all industries, the cost of materials to the firm is included in the firm's sales, even though that materials cost reflects the "sales" of another firm earlier in the production chain. As a result, firms further along the production chain will have higher sales, and thus lower reported R&D-to-sales ratios, even though R&D as a proportion of the firm's contribution to GDP (as measured by value added) might not be any lower than firms earlier in the production chain. While these R&D intensity ratios reflect the relative tendencies of companies to devote their own resources to R&D activities, they do not reflect the additional resources provided by the Federal Government (not included in this data series) that increase the actual amount of R&D performed by industry. Such Federal support for R&D varies greatly by industry. Therefore, any study of the broader question of how much total R&D is performed by industry would require supplemental data on Federal support in addition to the data provided in this report.

<sup>10</sup> Some considerations regarding "turbulence" and firm *entries* and *exits*:

An *entry* occurs when a firm reports conducting R&D or begins reporting investment in R&D for the first time, which in most instances reflects the emergence of a publicly-held company, usually through an initial public offering (IPO). Because such an *entry* usually reflects the relatively recent creation of a new enterprise, it is defined as causing turbulence. Occasionally, an *entry* reflects the creation of a new corporation as a spin off from a larger corporation (as was the case with Lucent Technologies). Such *entries* also reflect turbulence. In rare instances an *entry* occurs because a pre-existing public company takes up R&D for the first time.

An *exit* occurs when a firm permanently ceases reporting investment in R&D. In many instances this reflects a firm's acquisition by another company, either domestic or foreign, in which case it is no longer independently conducting R&D (e.g., Chrysler). *Exits* also occur when businesses cease operation. Such events are defined as causing turbulence. In very rare instances an *exit* occurs when a public company becomes private and is no longer included in the data series. In general a large number of firm *entries* in a given sector reflects relative ease of entrance that is likely associated with ready access to venture capital, rapid technological change, and in general a high degree of competitiveness. In contrast, frequent R&D *exits* may indicate rapid consolidation in a given sector or intense foreign competition. Low *entry* and *exits* may be associated with relative industry stability.

It is important to stress that the commencement or termination of R&D reporting is used here to reflect firm *entry* or *exit*, not technology activity. This is possible because this examination is limited only to firms that conduct R&D. The use of R&D in this instance does not imply that R&D itself or technology innovation generally is necessarily associated with industrial turbulence. Net sales is not an appropriate proxy measure of turbulence with regards to R&D firms since newer, small R&D-investing corporations may not realize positive net sales for a number of years. Irrespective of the specific measure, it should also be noted that the measurement of industry turbulence in the *U.S. Corporate R&D* data series is logically more accurate for technologically intensive industries in the data series than it is for industries that are less technology intensive. This is because the report's examination of *entries* and *exits* specifically excludes the many non R&D firms that compose the great bulk of non-technology intensive industries. For an in-depth discussion of the relationship of turbulence and technological innovation see BRIE Working Paper 114, *Industry Structure Dynamics and the Nature of Technology in the Hearing Instrument Industry*, by Peter Lotz, March 1998, <http://brie.berkeley.edu/~briewww/pubs/wp/wp114.html>.

<sup>11</sup> R&D intensity tends to increase with decrease in firm size for several reasons: As a practical matter, most R&D investments must be funded above a certain minimum level, implying that small firms might need to commit a disproportionately larger share of their operating expenses as R&D. In addition, as a given firm's sales increase, its R&D is more broadly applicable, suggesting that R&D need not expand as rapidly as sales. Finally, many new, smaller firms do not realize significant net sales in their first years as public corporations, and thus, in those first years the R&D/sales ratios may be relatively high, given that sales have not yet been well established.

<sup>12</sup> Freeman and Soete note, for example, "A number of economists have maintained that despite the heavy concentration of R&D expenditure in large firms,...small firms...account for...important

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inventions and innovations" (Chris Freeman and Luc Soete, *The Economics of Industrial Innovation: Third Edition*, The MIT Press, 1999, p. 232.)

<sup>13</sup> Stephen Roper, *Under-Reporting of R&D in Small Firms: the Impact on International R&D Comparisons*, *Small Business Economics*, March 1999, Vol.12 No.2, pp 131-135.

<sup>14</sup> Includes "BioScan company profiles" provided by *BioWorld Online* at [http://www.bioworld.com/servlet/com.accumedia.web.Dispatcher?next=bioScan\\_companyList](http://www.bioworld.com/servlet/com.accumedia.web.Dispatcher?next=bioScan_companyList), *BioScorpio* at <http://www.bioscorpio.com/biostocks.htm>, and *NetSci's YellowPages* at <http://www.netsci.org/Resources/Biotech/Yellowpages/>.

<sup>15</sup> Guidelines for identifying biotech companies approximated those of *BioAability* which states that it employs "a strict uniform set of criteria to determine whether or not a company is a biotechnology firm (i.e., applying the following biotechnologies in its R&D or manufacturing program -- recombinant DNA (gene splicing), hybridoma, protein engineering, large-scale cell culture, new fermentation processes, liposomes and protein drug delivery and other related technologies)."

<sup>16</sup> Because most biotech databases are focused on currently active firms, firm counts for earlier years may understate the actual number of firms.

<sup>17</sup> Biotech firm-size categories were developed in the same fashion as for all R&D corporations. As such, the same considerations apply as discussed in that prior section of this report.

<sup>18</sup> Some of this propensity towards smallness may be a function of the biotech firm selection process discussed above, which rules out larger firms like pharmaceuticals. Nevertheless, it is likely mostly due to fundamentals of the sector such as its focus on research, which is generally less employment intensive than are production activities.

<sup>19</sup> Because firm-size category data only includes firms that were extant in all three years, 1998-2000, growth rates are likely to be higher than for the larger population of biotech firms that includes exits that are often robust firms acquired by foreign or non-biotech firms.

<sup>20</sup> Cassandra Ingram, Economics and Statistics Administration, U.S. Department of Commerce.

<sup>21</sup> Foreign sales do not include a percentage for 1995.

<sup>22</sup> Again, some caution should be used in considering the growth rates of earlier years since the identification of no longer existing biotech firms increasingly difficult further back in time. Hence, understatement of sales and other indices amounts may increase the earlier the year, thereby possibly inflating growth rates.